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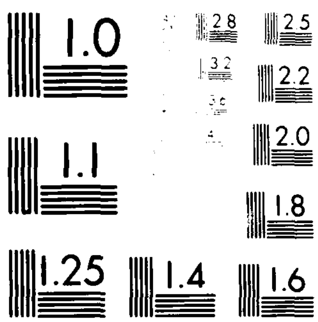

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NAVY EXPERIMENTAL DIVING UNIT

Report 13-77

DIVERS' HEATING HOSE COMPARISON STUDY

Distribution Unlimited

GOLDEN ANNIVERSARY 1927-1977

EXPERIMENTAL DIVING UNIT

UNITED STATES NAVY

PANAMA CITY, FLORIDA 32407

SUMMARY REPORT

on

DIVER'S HEATING HOSE COMPARISON STUDY

to

COMMANDING OFFICER
U. S. NAVY
EXPERIMENTAL DIVING UNIT

under

CONTRACT NO. N61331-77-M-2421

November, 1977

by

Harold F. Link
Peter S. Riegel

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Approved before mailing by DW Frink,
PS Riegel, and HF Link

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DW Frink/GM McClure/644 Fil
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December 13, 1977

CDR C. A. Bartholomew, USN
Commanding Officer
Navy Experimental Diving Unit
Panama City, Florida 32407

Dear CDR Bartholomew:

Enclosed are four copies of the report "Diver Heating Hose Comparison Study". The research resulted in successful identification of several hoses suitable for diver heating use.

Submission of this report represents completion of the contract.

In order to pinpoint more accurately the characteristics of the hoses some further research and testing may be desirable. Should you desire, we will be happy to assist in any further extension of the effort.

We have enjoyed working with NEDU on this interesting task, and look forward to working with you again. If you have any questions, comments, or suggestions concerning the report, please call me at (614)424-4009.

Sincerely,

Peter S. Riegel
Research Engineer
Equipment Development
  Section

PSR:djs

Enc. (4)

xc: Mr. W. R. Bergman, OOC (1tr w/rpt)

Receiving Officer -- (1tr only)
Naval Coastal Systems Laboratory
Building 321
Panama City, Florida 32401

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ABSTRACT

Diver's heating hose is used to transport heated sea water from the surface to a diver to provide him with thermal protection. At present no criteria exist for determining the suitability of a given hose for this application. This report describes how requirements of hot water heating systems were used to define hose evaluation criteria. These criteria were then applied to findings of a comprehensive survey of commercially available hoses. As a result, a number of hoses are identified as suitable for diver heating.

–D–

SUMMARY REPORT

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EXPERIMENTAL DIVING UNIT

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November, 1977

INTRODUCTION

The use of hot water heating systems for diver thermal protection has increased in recent years. The operation of these systems is quite simple. Sea water is heated at the surface and then pumped through an umbilical hose to the diver. At the diver it is directed through a special unit which distributes the heat to all parts of the body. Finally, the water is exhausted from the suit through a number of "leak" paths. In deep dives, the water may also be directed to a heat exchanger to heat the diver's breathing gas.

Presently the U. S. Navy has no established criteria for determining whether a given hose will be suitable for conveying hot sea water to the diver. This task was initiated to define practical criteria by which hoses could be judged and use these criteria to identify suitable hoses.

SUMMARY

In order to insure that the hoses recommended in this report would meet the operational requirements of present and proposed Navy hot water heating systems, the task consisted of a sequence of five steps. These steps are summarized below while more detailed explanations are included in the later sections of this report.

First, the operational requirements of the hoses were outlined in general form. Review of the ASR-21 and the Mark 1 Mod 0 heating systems revealed general pressure, temperature, and flow requirements for hot water systems.

These requirements were outlined in a letter of inquiry to hose manufacturers listed in the Thomas Register. Limited response to the letter prompted a more direct second effort to obtain information from manufacturers. Telephone calls and a second, simplified letter resulted in the identification of 22 companies that could provide potentially suitable hoses.

Theoretical analyses were also conducted to correlate heat and pressure loss to hose characteristics and operating conditions. These correlations were then used to examine two of the most severe diver heating scenarios. It was shown that the worst case of application is a deep water dive where hose inlet temperatures and pressures might be as high as 175°F and 185 psi respectively.

With the information gained in these first three steps of the program, Battelle investigators and NEDU personnel were able to make the final definition of hose evaluation criteria. These criteria can be used to judge not only the hoses identified in this survey but also new hoses which will undoubtedly be considered in the future.

Finally, the hoses which had been identified in the market survey were evaluated against the criteria. In addition to manufacturers information, hose samples were obtained for visual examination of quality. Ten hoses were selected as meeting the established criteria.

RESULTS

The results of this task are summarized in the following figures and tables. Table 1 is a matrix of the most suitable hoses found in the survey along with comparative characteristics and prices. All of the hoses included in this list should be suitable for diver hot water heating. Selection of a particular hose may be based on availability, cost, or previous experience.

Figure 1 is a graph of flow-induced pressure loss to be expected for hoses of different inside diameters and lengths. The graph can be used to estimate the required inlet pressure for a particular hose and flow rate. Alternatively, it can be used to select a hose of suitable diameter for an intended flow and inlet pressure.

Table 2 indicates required inlet temperatures for different sized hoses operating in water of various temperatures. It can be used by the dive master to set the heating system controls at the start of a dive. Diver's comments will then be used to adjust inlet temperatures for variations in operating conditions or for his comfort.

It should be noted that these values are derived from theoretical calculations which include a number of assumptions. Actual heat losses will undoubtedly differ from those predicted by theory. Experience in diver heating operations will ultimately prove to be the best guide.

CONCLUSIONS AND RECOMMENDATIONS

In the course of completing the hose survey and theoretical calculations, our research has led us to conclude the following

(1) Hoses suitable for diver's hot water heating systems are available from many sources. No specific source has been shown to be clearly superior for all applications.

TABLE 1. 1/2-INCH HOSES FOUND TO BE MOST SUITABLE FOR DIVER HEATING UMBILICALS

Manufacturer	Address	Hose Name	Inlet Temp(1), F	Weight in Air, lb/100 ft	Weight in Water, lb/100 ft	Length Available	Cost(2), $/100 ft
Aeroquip Corp. (Industrial Div)	1225 W. Main St. Van Wert, OH 45891	FC-285-08	143	28	-5	300 ft min	164
Amazon Hose and Rubber Co.	130 N. Jefferson St. Chicago, IL 60606	Deep Sea Diving	147	30	-2	Reel(3)	55
Dayco Corp. (Industrial Sales Div)	333 W. First St. Dayton, OH 45401	Thoro-Flo All Purpose	147	29	-3	300-600 ft	37
Diving Unlimited International	1148 Delevan Dr. San Diego, CA 92102	Hot Water Diver	150	19	-12	Reel	160
Diving Unlimited International	1148 Delevan Dr. San Diego, CA 92102	Hot Water Bell	130	61	+17	Reel	197
Electric Hose and Rubber Co.	12th and Dure Sts. Wilmington, DE 19899	MultiPurpose	150	26	-5	Reel	43
Gates Rubber Co.	999 S. Broadway Denver, CO 80217	Plant Master 119B (315 psi)	149	27	-4	Reel	114
Goodrich, B. F. (Industrial Products)	500 S. Main St. Akron, OH 44318	Highflex	166	20	-7	Reel	107
Goodyear (Industrial Product Div)	E. Market St. Akron, OH 44316	Ortac (350 psi)	138	38	+2	Reel	85
Parker Hannifin Corp. (Hose Products Div)	30240 Lakeland Blvd. Wickliffe, OH 44092	Parflex 540N	161	12	-19	300 ft	105
Porter, H. K., Co. (Thermoid Div)	Porter Building Pittsburgh, PA 15219	Versicon	147	29	-3	2/600 ft reel	51
Uniroyal (Industrial Products)	Middleburg, CT	P-290	147	29	-3	Reel	111
White, H. S., Co., Inc.	2056 N. Dixie Hwy. Fort Lauderdale, FL 33305	Hot Water Hose	150	26	-7	Reel	56

(1) Intended to show the effect of hose outside diameter, these numbers are the predicted inlet temperatures required to supply a diver under the following conditions: Flow = 3 gpm, Outlet Temp. = 105 F, Ambient Water Temp. = 40 F, Heat Transfer Characteristic (k) = 0.12 Btu/hr-ft^2-F, Length = 600 ft. The hose's outside diameter is the only variable represented in the calculation of these numbers.
(2) Cost based on an order of three lengths of 300 ft. hoses (may require splices).
(3) Reel lengths are industry standards of 300-450 ft. of hose per reel, a maximum of three lengths per reel, the shortest length is at least 10 percent (50 ft.) of total length of hose on the reel.

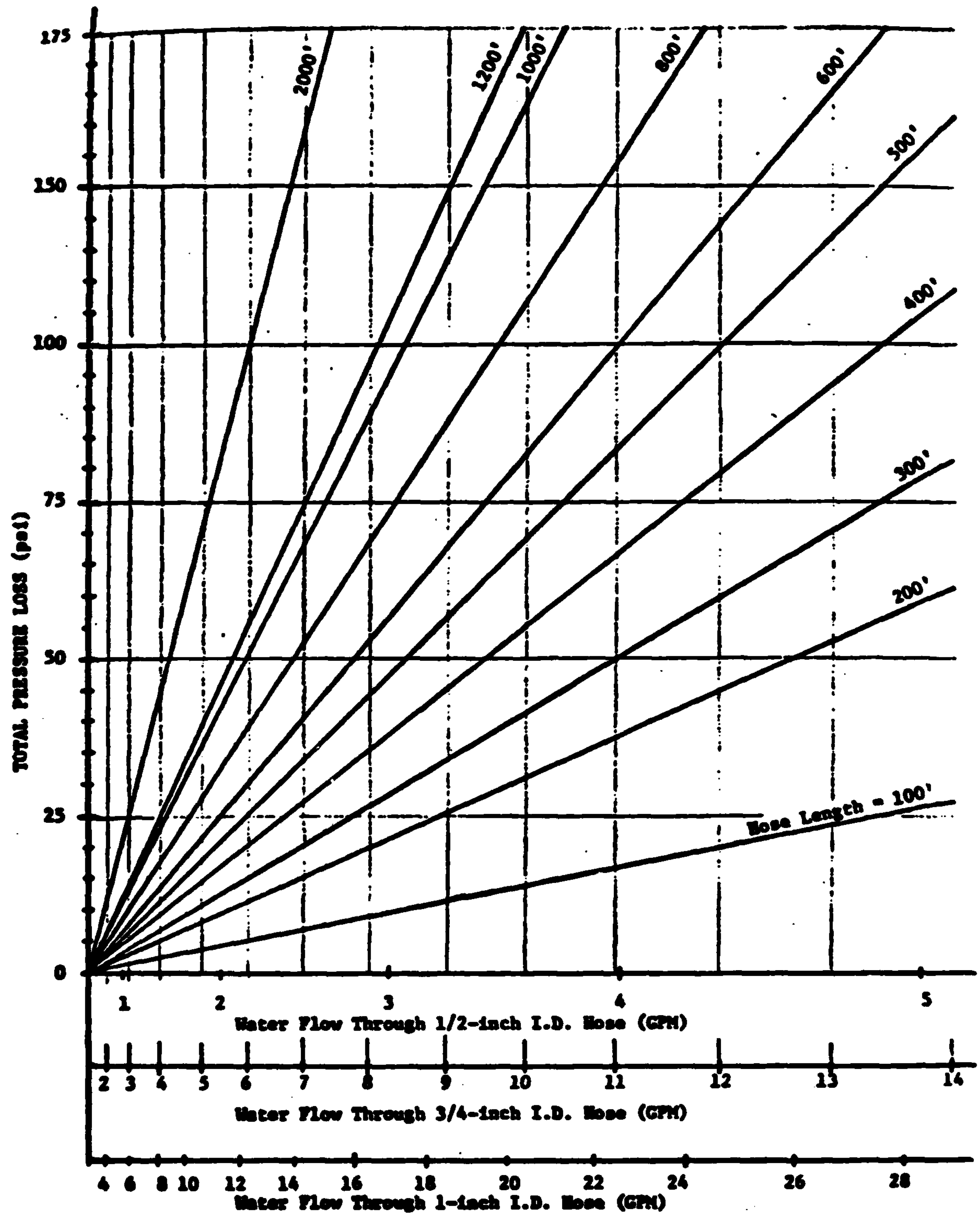

FIGURE 1. CALCULATED PRESSURE LOSS VS. WATER FLOW RATE FOR UMBILICAL HOSES OF VARIOUS DIAMETERS AND LENGTHS

TABLE 2. REQUIRED INLET TEMPERATURES FOR HOT WATER FLOW THROUGH 1/2-INCH HOSE DISCHARGING AT 105 F

Umbilical Length, Feet	Ambient Water Temperature, F							
	35	40	45	50	55	60	65	70
				Water Flow = 2 GPM				
100	114	114	113	112	112	111	110	110
200	125	123	122	121	119	118	116	115
300	137	135	132	130	128	125	123	121
400	150	147	144	141	137	134	131	128
500	166	161	157	153	148	144	140	135
600	183	178	172	166	161	155	150	144
				Water Flow = 3 GPM				
100	111	111	110	110	109	109	108	108
200	118	117	116	115	114	113	112	111
300	125	123	122	121	119	118	116	115
400	133	131	129	127	125	123	121	119
500	141	139	136	133	131	128	126	123
600	150	147	144	141	137	134	131	128
				Water Flow = 4 GPM				
100	110	109	109	109	108	108	108	107
200	114	114	113	112	112	111	110	110
300	119	118	117	116	115	114	113	112
400	125	123	122	121	119	118	116	115
500	131	129	127	125	123	122	120	118
600	137	135	132	130	128	125	123	121

(2) In general, manufacturers do not have specific data on hose characteristics important for this application, specifically heat insulation properties and life expectancy when flowing hot, possibly oil contaminated, salt water.

(3) Until results from laboratory testing and/or field evaluations are obtained, it is not possible to define completely the suitability of a particular hose for this application.

Therefore, we recommend that the Navy Experimental Diving Unit or another qualified, diving-oriented group be tasked to test the hoses selected in this report. The review need not comprehensively investigate all aspects of the hoses. However, critical characteristics, such as heat transfer properties and resistance to oil and hot salt water, should be defined as completely as possible.

RESEARCH PROCEDURE

The research efforts of this task were conducted according to the following five steps:

(1) Preliminary Definition of Hose Requirements

(2) Market Survey

(3) Theoretical Analyses

(4) Final Definition of Hose Evaluation Criteria

(5) Selection of Suitable Hoses.

These steps are discussed in detail in the following sections of the report.

Preliminary Definition of Hose Characteristics

The first step in the selection of hoses for this application was to review the existing hot water heating systems and to identify some of the critical environment conditions which the heating hose must withstand.

Therefore, Navy representatives were contacted who had experience with hot water systems. In addition, reference was made to a Battelle report "Design Review of Diving Support Systems Aboard ASR-21", SUPDIV Report 1-72 by J. A. Henkener, et al.

From the information gathered from these sources, the following hose characteristics were defined:

(1) Working Pressure - 200 psig
(2) Temperature Range - 0°-240°F
(3) Good Heat Insulation
(4) Compatibility with Seawater, Petroleum Oil and Mild Cleaning Solvents
(5) Inside Diameters from 1/2 in. to 1-1/2 in.
(6) Lengths from 100 to 1000 feet.

It was felt that if hoses of these characteristics were identified they would be able to withstand the most severe conditions likely to be found in a diver's heating system.

Market Survey

Once the preliminary hose requirements were established, a survey of commercially available hoses was conducted. A list of hose manufacturers was compiled from the Thomas Register. Each manufacturer was sent a letter of inquiry containing the hose requirements and asking for technical and price information on hoses which could meet the requirements.

The response to this letter was not good. Many companies wrote back saying that they could not make such a hose -- but not saying why. Most companies did not respond at all. With the benefit of knowledge gained since that letter was written, it became obvious that: (1) The letter was too long and complicated for easy response by manufacturers and (2) the temperature and length requirements were too severe.

When it became obvious that the letter of inquiry was not producing the desired results, a second attempt was made. This time a number of large

companies were contacted by phone. Other companies were sent a short, direct letter asking for information. Some companies were dropped from consideration because their major product line did not include reinforced rubber hose.

The response to this second effort was much more positive. Information was obtained from companies which could provide potentially suitable hoses. This information was compiled into matrix form and is shown in Appendix A. Also included in this appendix is a list of all companies contacted and their responses.

Theoretical Analyses

Concurrent with market survey efforts, a number of theoretical analysis were undertaken. Two factors were investigated, pressure loss and heat loss. Both factors are influenced by and, in turn, influence hose characteristics. The following sections of this report show how these factors are affected by hose characteristics and operating conditions.

Flow-Induced Pressure Loss

The inlet pressure for hot water hoses can be determined by calculating flow induced pressure losses. Other factors such as elevation of the inlet of the hose relative to the diver produce only small effects in comparison*. The pressure loss caused by flow can be calculated from the formula

$$\Delta P = .000216 \frac{fL\rho Q^2}{d^5} \qquad (1)^{**}$$

where

ΔP = Pressure loss, psi

L = Hose length, feet

* A static pressure head is produced because of the difference in density of hot sea water vs. cold. However, even in the worst case of an 850' dive the static head will not be more than 5 psi. This error is partially offset by the location of the hot water source above the ocean surface.

** Equation derived from Equation 3-14 in Crane's Flow of fluids Through Valves, Fittings, and Pipe, Crane Co., 1969.

ρ = Fluid density, lb/ft^3

Q = Flow, gpm

d = Inside diameter, inches

f = Friction factor.

Since the density of sea water is about 64 lb/ft^3, the friction factor for smooth bore hoses of 1/2 inch to 1 inch I.D. is about 0.24, and the outlet pressure is zero, Equation (1) can be simplified to

$$P \text{ inlet} = .033 \frac{LQ^2}{d^5} \tag{2}$$

This relationship is shown graphically as Figure 1 of this report.

Temperature Loss

Because the water inside the hose is hotter than the water surrounding the hose, some heat loss is expected. The question arises: what must the inlet temperature be to insure that the outlet temperature at the diver is adequate? To answer this question we can make use of an equation derived in Reference 1 (Equation 6, Page 42).

$$t_1 = (t_3 - t_2) e^{\frac{2\pi KL}{mC \ln(d_2/d_1)}} + t_2 \tag{3}$$

where:

t_1 = Temperature of water entering the hose, °F

t_2 = Temperature of surrounding water, °F

t_3 = Temperature of water leaving the hose, °F

K = Thermal conductivity of the hose material, Btu/hr-ft-°F

L = Length of the hose, feet

m = Water mass flow rate, lbs/hr

C = Specific heat of water, Btu/lb-°F

d_1 = Inside diameter of hose, inches

d_2 = Outside diameter of hose, inches.

In the derivation of this equation the following assumption is made:

(1) The inside and outside of the hoses are at the temperature of the water with which they are in contact. The effect of current is therefore accommodated although a slightly reduced heat loss would be expected when diving in still water.

Equation (3) can be simplified if a few additional assumptions are made:

(2) The thermal insulating properties of common hose materials (EPDM, BUNA N, Neoprene, etc.) are approximated by the factor,

$$K = 0.12 \ \frac{\text{BTU}}{\text{hr-ft-°F}} .$$

This number will be affected by variances in material formulations and by the number and types of reinforcing braids. However, temperature requirements based on this number correspond closely with curves available from Diving Unlimited International. Actual K factors will probably range from .09 to .18 BTU/hr-ft -°F.

(3) The ratios of hose O.D. to hose I.D. (outside to inside diameters) for the hoses under consideration are 1.81 for 1/2-inch I.D., 1.67 for 3/4-inch I.D., and 1.50 for 1-inch I.D. Again, variation in these ratios can be expected as shown in the ~~hose~~ matrix in Appendix A.

In addition, the following substitutions are made:

$$m = 479\ Q \ (Q \text{ is flow in gals/min})^{*}$$

$$C = 1 \text{ BTU/lb-°F}$$

and

$$K_1 = \frac{2\pi K\ Q}{mC \ln (d_2/d_1)}$$

$$= \frac{2\cdot\pi\cdot 0.12\cdot Q}{479\cdot 1\cdot \ln(d_2/d_1)}$$

---

* $m = Q\cdot(\text{gal/min})\cdot 64(\text{lb/ft}^3)\cdot 60(\text{min/hr})\cdot 0.13(\text{ft}^3/\text{gal})$.

Now Equation (3) may be written

$$t_1 = (t_3 - t_2)e^{K_1 \frac{L}{Q}} + t_2 \qquad (4)$$

where

t_1 = Require inlet temperature, °F

t_2 = Ambient sea water temperature, °F

t_3 = Desired outlet temperature, °F

L = Length of hose, feet

Q = Flow through hose, gpm

$K_1 = .00250 \frac{GPM}{ft}$ for 1/2" I.D. hose

$= .00286 \frac{GPM}{ft}$ for 3/4" I.D. hose

$= .00362 \frac{GPM}{ft}$ for 1" I.D. hose.

Equation (4) was used to generate Table 2 presented on page 6 of this report.

Although assumptions 2 and 3 are useful for generating Table 2, it is desirable to determine the errors in t_1 which might be produced if the thermal insulating properties or O.D. to I.D. ratios of the hases deviate from the assumed values. Therefore, a few severe cases were considered in which the K values and the O.D./I.D. ratios were varied from their minimum to maximum expected values.

For these cases surrounding water temperature (t_2), desired outlet temperature (t_3) and flow rate (Q) are constant at values of 40°F, 105°F, and 3 gpm respectively.

As seen in Figure 2, neither the K value or the O.D./I.D. ratio affect the required inlet temperature to a great extent with a 300 foot umbilical. However, with a 600 foot umbilical (assuming its entire length is immersed) the effect of a large K value or small O.D./I.D. ratio become significant. It would seem apparent, then, that when a short, 300 ft, umbilical is required, criteria such as price, availability, or proven durability might be the primary criteria to use. Whereas, with longer umbilicals, closer attention must be given to the hose's thermal insulation qualities.

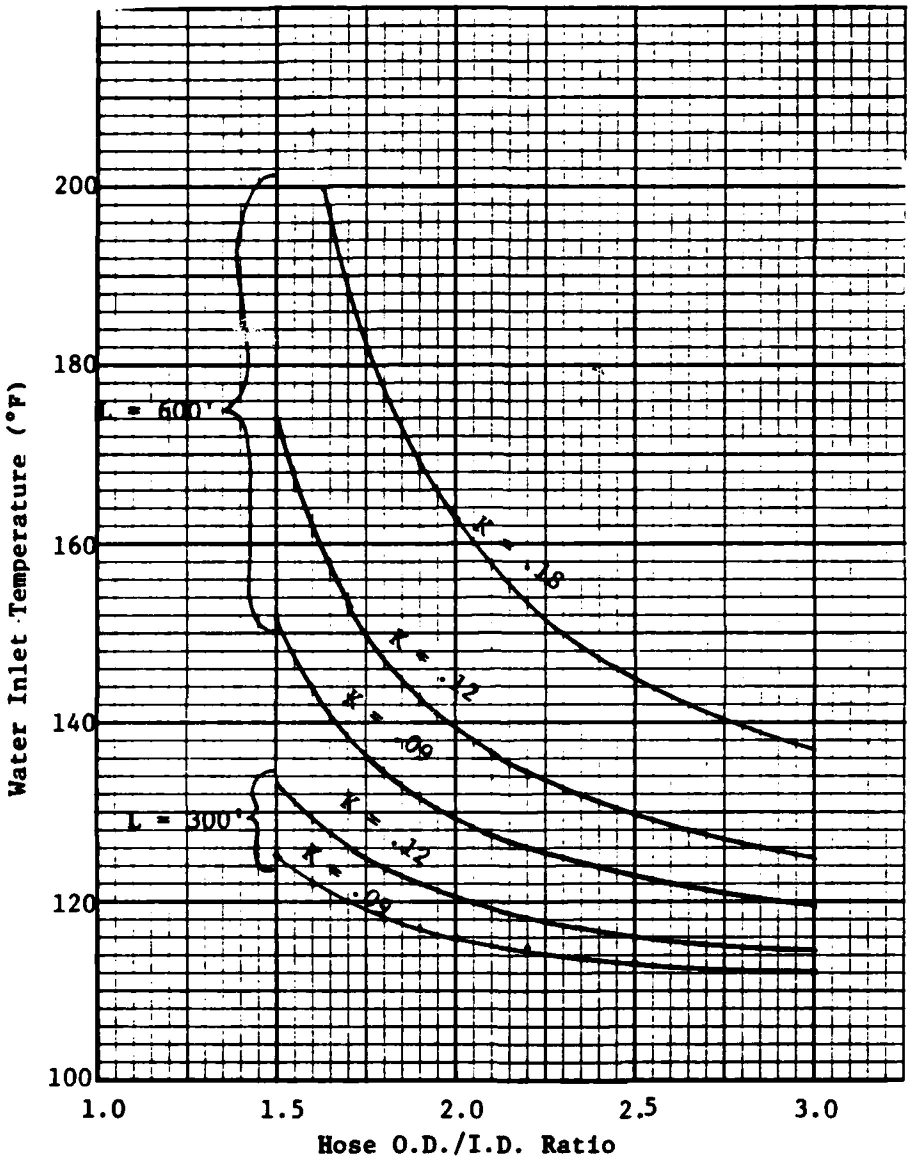

FIGURE 2. EFFECT OF HOSE INSULATION PROPERTIES ON REQUIRED INLET TEMPERATURES FOR 300' AND 600' UMBILICALS

Worst Case Analysis

Using Figure 2 and the heat-loss Equation (4), we can estimate the "worst case" pressure and temperature requirements. With less demanding applications, pressures and temperatures will be significantly less. Two cases were investigated: (1) a deep dive to 850 feet where divers are supported from a PTC and (2) a mixed gas dive to 300 feet where divers are independently supplied from the surface through 600 feet umbilicals.

Case 1--850 Foot Dive With PTC. The conditions for this dive scenario are:

Three divers supported from a PTC at 850 FSW
Length of diver's umbilicals - 300 feet
Length of bell umbilical - 1200 feet
Flow to each diver - 3 GPM
Water temperature required at diver - 105 F
Ambient water temperature - 40 F
Assumptions (2) and (3) valid -- e.g., K = 0.12 BTU/hr-ft-°F and
O.D./I.D. = 1.80 for 1/2" hose
= 1.67 for 3/4" hose
= 1.5 for 1" hose.

Analysis of requirements is completed according to the following procedure:

(a) Size diver and bell umbilicals for flow capability

According to Figure 1, pressure losses through hoses are:

300 feet of 1/2-inch I.D. hose flowing 3 GPM	=	3 psi
1200 feet of 3/4-inch I.D. hose flowing 9 GPM	=	125 psi
Estimated valve and fittings losses	=	30 psi
Total pressure required at source	=	183 psi

If 183 psi is too great or if 4 divers will be supplied, then 1-inch I.D. bell umbilical would be recommended:

300 feet of 1/2-inch I.D. hose flowing 3 GPM	=	28 psi
1200 feet of 1-inch I.D. hose flowing 12 GPM	=	53 psi
Estimated valve and fittings losses	=	30 psi

(b) Estimate water supply temperature. Temperature of water at the bell is determined by estimating the heat losses through the 1/2-inch I.D. hoses using Equation (4) (or Table 1):

$$t_{bell} = (t_{diver} - t_{ambient})e^{K_1\frac{L}{Q}} + t_{ambient}$$

$$= (105-40)e^{.00250\cdot\frac{300}{3}} + 40$$

$$= 123°F$$

Knowing the required temperature at the bell we can calculate the heat losses through both 3/4-inch and 1-inch I.D. bell umbilicals:

$$t_{surface} = (t_{bell} - t_{ambient})e^{K_1\frac{L}{Q}} + t_{ambient}$$

$$= (123-40)e^{.00286\frac{1200}{9}} + 40$$

$$= 162°F \text{ for 3/4-inch I.D. hose @ 9 GPM}$$

Using the same procedure we can see the effect of substituting 1-inch I.D. hose and different flow rates:

For 1-inch hose @ 9 GPM

$T_{surface}$ = 175 F

For 1-inch hose @ 12 GPM

$T_{surface}$ - 159 F

Case 2--300 Foot Dive With Independent Surface Support. The conditions for this dive scenario are:

Each diver individually supplied from the surface to 300 FSW

Length of umbilical - 600 feet

Flow to each diver - 3 GPM

Water temperature required at diver - 105 F

Ambient water temperature - 40 F

Assumptions (2) and (3) valid.

As in Case 1, the umbilicals are first sized for flow capability:

(a) Size umbilicals for flow capability

According to Figure 1, pressure losses are:

600 feet to 1/2-inch I.D. hose flowing 3 GPM	= 57 psi
Estimated valve and fittings losses	= 25 psi
Total pressure required at source	= 82 psi

(b) Estimate water supply temperature

Using Equation 4 (or Table 1):

$$t_{surface} = (t_{diver} - t_{ambient})e^{K_1\frac{L}{Q}} + t_{ambient}$$

$$= (105-40)e^{.00250\frac{600}{3}} + 40$$

$$= 147°F.$$

Having completed this analysis, we may conclude that the 850-foot dive will make the greatest demands on the supply equipment and the hoses. The maximum pressure in that case could be 183 psi and the maximum temperature could be 175 F. Due to the assumptions made in these analyses, it is reasonable to require hoses to withstand temperatures to 190°F and pressures to 200 psi.

Final Definition of Hose Evaluation Criteria

Once the market survey and the theoretical analyses were completed, a meeting was held with Navy representatives of the Experimental Diving Unit to define the final hose evaluation criteria. These criteria would be used to judge the most suitable hoses for Navy use.

Some of the criteria were easily quantified so that potential hoses could be evaluated purely on manufacturer's information. With other criteria, it was not as easy to determine if a potential hose would be suitable or not. Items on the final list are explained in the following paragraphs.

Size	--	1/2-Inch I.D. hoses only would be considered. This size is most suitable for the 2-4 GPM flows required for individual diver umbilicals. Bell umbilicals (3/4-inch and 1-inch I.D.) would be considered on a special basis.
Pressure	--	200 Psig working pressure, 800 psi burst pressure minimum. Although pressures this high would probably not be encountered, the extra insulation and factor of safety of this rating justifies any additional weight or cost.
Temperature	--	0 to 190°F. Hose should be capable of extended exposure to salt water at 190°F and should remain flexible at 0°F.
O.D./I.D. Ratio	--	Should be as large as possible for long umbilicals. Smaller ratios for short umbilicals or "whips" are acceptable.
Flexibility	--	Should be flexible but not liable to collapse during normal handling.
Weight	--	Weight of hose in sea water should be as close to zero as possible. A negative weight (floater) is less desirable than a positive weight hose. The characteristics of the hot water hose should be considered in respect to the characteristics of the other hoses, cables, etc., in the umbilical assembly however. A heavy hose might serve well when incorporated in an otherwise bouyant umbilical.
Tube Material	--	Compatible with 190°F sea water and dilute concentrations of oil.
Braid	--	Synthetic fiber braid or spiral wrap. Natural fiber and carbon steel braids are too susceptible to degradation in a sea water environment.

Cover Material -- Compatible with sea water, detergents, and strong concentrations of oil. Resistant to ozone, UV radiation and weather checking.

Color -- Any color is acceptable, however, the carbon black pigment used in black hose is generally considered to provide superior weathering characteristics.

Length -- Continuous lengths preferable but purchases in reel lengths is acceptable if individual umbilicals can be assembled with no more than two splices.

Cost -- No maximum costs specified but lower priced hose is preferable if quality is comparable.

Selection of Most Suitable Hoses

After completing the above steps, it was a straightforward procedure to select the most suitable hoses for divers' heating. The hoses which were selected appear to satisfy all of the established requirements. They may, however, vary in durability or heat insulation-characteristics which are difficult to measure without laboratory or field evaluations.

In addition to selecting hoses based on information available from manufacturers, sample lengths of hoses were obtained for visual examination. No discrepancies from manufacturer-provided information were noted with any of the samples. The samples were labeled and delivered to the Navy Experimental Diving Unit.

REFERENCES

1. Crane, "Flow of Fluids Through Valves, Fitting, and Pipe", Crane Co., 1969.

2. Henkener, J. A., "Design Review of Diving Support Systems Aboard ASR-21", SUPDIV Reprot No. 1-72, April, 1972.

3. U. S. Navy Diving Gas Manual, Second Edition, NAVSHIPS 0994-003-7010, June, 1971.

4. "Unlimited Hot Water System", a pamhlet by Diving Unlimited International.

TABLE A-1. MATRIX OF CHARACTERISTICS OF DIVERS HEATING HOSE

1/2-Inch I.D. Hose

Company	Hose Name	OD/ID	Number of Braids	Working Pressure (psi)	Maximum Temperature (°F)	Weight (lbs/100')	Tube Material	Cover Material	Color	Length	Cost[1] ($/100')
Abbot	6160	1.75	2	250	190	28	EPDM	EPDM	Black	Reel	28
Amazon	Deep Sea Diving	1.81	4	300	240	30	Nycal	Neoprene	Red	Reel[2]	55
Aeroquip	FC285-08	1.88	2	1000	200	28	Synthetic Rubber	Neoprene	Black	300' Min	164
Baxter[3]	P970	1.75	2	250	200	24	EPDM	EPDM	Red	Reel	66
Boyd	Gen'l Purpose	1.75	2	250	--	18	EPDM	EPDM	Black	Reel	--
Dayco	Thermo-Flo All Purpose	1.81	2	300	240	29	Buna N	Neoprene	Black	300-600'	37
Diving Unlimited	Hot Water Diver	1.75	2	600	200	--	Gum Rubber	Gum Rubber	Black	Reel	180
Diving Unlimited	Hot Water Bell	2.50	2	600	200	--	Gum Rubber	Gum Rubber	Black	Reel	197
Electric Rubber and Hose	Multipurpose	1.75	2	250	200	26	Nitrile	Neoprene	Black	Reel	43
Gates	Plant Master 119B	1.60	1	250	212	24	Buna N	Neoprene	Black	Reel	99
Goodrich, B.F.	Highflex	1.56	1	250	200	20	Neoprene	Neoprene	Red	Reel	50
Goodyear[4]	ORTAC	1.81	1	300	190	22	Chemigum	Chemivic	Red	Reel	74
Goodyear[4]	ORTAC	2.06	2	350	190	38	Chemigum	Chemivic	Red	Reel	85
Jason (Pirelli)	Pressure SP 275H/L (0.512"ID)	2.15	1	206	240	--	SBR	SBR	Black	328'	119
Manhattan	All-Serve	1.81	2	300	200	26	Nitrile	Nitrile/Vinyl	Black	Reel	75
Parker Hannifin	Parflex 540N	1.60	1	2000	200	12	Nylon	Polyurethane	Black	300'	105
Porter, H. K.	Versicon	1.81	4	300	200	28.5	Nitrile	Neoprene	Red	2/600'Reel	51

Footnotes appear on Page

TABLE A-1. (Continued)

1/2-Inch I.D. Hose

Company	Hose Name	OD/ID	Number of Braids	Working Pressure (psi)	Maximum Temperature (°F)	Weight (lbs/100')	Tube Material	Cover Material	Color	Length	Cost[1] ($/100')
Resistoflex	R-502	1.38	1	200	200	18	TFE	Polyurethane	Silver	1000'	793
[illegible][5]	Insulated Hot Water Supply	2.56	1	200	190	55	EPDM	EPDM	Black	400-600	328
Titeflex	106578-12-3600	1.52	1	1500	500	55	TFE	Urethane/ Silicone	---	1000'[6]	187[7]
Uniroyal	P290	1.81	2	300	200	29	NITRILE	OZEX	Green	Reel	111
White, H. S.	Hot Water Hose	1.75	2	250	200	24	PARACRIC	OZEX	Red	Reel	56

TABLE A-1. (Continued)

3/4-Inch I.D. Hose

Company	Hose Name	OD / ID	Number of Braids	Working Pressure (psi)	Maximum Temperature (°F)	Weight (lbs/100')	Tube Material	Cover Material	Color	Length	Cost[1] ($/100')
Abbott	6208	1.54	2	200	190	43	EPDM	EPDM	Black	Reel	42
Amazon	Deep Sea Diving	1.67	4	300	240	40	Hycar	Neoprene	Red	Reel	80
Baldwin	Black Wingfoot	1.58	2	300	200	36	Synthetic Rubber	Synthetic Rubber	Black	Reel	111
Baxter[3]	P970	1.56	2	200	200	37	EPDM	EPDM	Red	Reel	89
Boyd	General Purpose	1.50	2	200	--	37	EPDM	EPDM	Black	Reel	--
Dayco	Thoro-Flo All Purpose	1.67	2	300	240	48	Buna N	Neoprene	Black	300-600'	54
Electric Hose and Rubber	Air and Water	1.56	2	200	--	40	EPDM	EPDM	Black	Reel	70
Gates	Plant Master 19B	1.09	1	250	212	32	Buna N	Neoprene	Red	Reel	113
Gates	Plant Master 19B	1.25	2	315	212	51	Buna N	Neoprene	Red	Reel	--
Goodrich, B.F.	BFG 300 G.S.	1.67	4	300	200	40	EPDM	EPDM	Black	Reel	70
Goodyear[4]	ORTAC	1.58	1	300	190	35	Neoprene	Chemivic	Red	Reel	99
Goodyear	ORTAC	1.83	2	350	190	54	Neoprene	Chemivic	Red	Reel	
Jason (Pirelli)	Press. SP 275 N/L .748 I.D.	1.79	1	206	240	--	SBR	SBR	Black	328	151
Manhattan	All-Serve	1.67	2	300	200	40	Nitrile	Nitrile/ Vinyl	Black	Reel	--
Myers-Sherman	Vactor Orange	--	--	1250	300	--	Polyamide	Hytral	Orange	400-500'	200
Parker Hannifin	Parflex 540N	1.39	1	1250	200	17.3	Nylon	Polyure- thane	Black	300'	176
Porter, H. K.	G. P. Spiral	1.58	4	275	200	44	Nitrile	EPDM	Red	2/600' Reel	--
Swan[5]	Insulated Hot Water Supply	2.04	--	200	200	69	EPDM	EPDM	Black	200-350'	414
Uniroyal	P290	1.56	[illegible]	200	200	37	Nitrile	Ozex	Green	Reel	--
White, H. S.	Hot Water Hose	1.54	2	250	200	44	Paracril	Ozex	Red	Reel	78

TABLE A-1. (Continued)

1-Inch I.D. Hose

Company	Hose Name	OD/ID	Number of Braids	Working Pressure (psi)	Maximum Temperature (°F)	Weight (lbs/100')	Tube Material	Cover Material	Color	Length	Cost[1] ($/100')
Abbott	Water Hose(Special)	1.47	2	300	790	50	EPDM	EPDM	Black	Reel	94
Amazon	Deep Sea Diving	1.47	4	300	240	60	Hycar	Neoprene	Red	Reel	106
Baldwin	Black Wingfoot	1.50	2	300	200	55	Synthetic Rubber	Synthetic Rubber	Black	Reel	148
Baxter[3]	P970	1.47	2	200	200	56	EPDM	EPDM	Red	Reel	133
Boyd	General Purpose	1.47	2	200	--	56	EPDM	EPDM	Black	Reel	--
Boyco	Thoro-Flo All Purpose	153	2	300	240	63	Buna N	Neoprene	Black	300-500'	---
Electric Hose and Rubber	Air and Water	1.50	2	200	---	65	EPDM	EPDM	Black	Reel	98
Gates	Plant Master 19B	1.38	1	250	212	47	Buna N	Neoprene	Red	Reel	---
Gates	Plant Master 19B	1.50	2	315	---	64	Buna N	Neoprene	Red	Reel	--
Goodrich, B.F.	RPC300 G.S.	1.47	4	300	200	50	EPDM	EPDM	Black	Reel	80
Goodyear[4]	ORTAC	1.50	1	300	190	49	Chemigum	Chemivic	Red	Reel	122
Goodyear[4]	ORTAC	1.58	2	350	190	57	Chemigum	Chemivic	Red	Reel	151
Jason (Pirelli)	TRT702 .984ID	1.60	2	206	240	--	SBR	SBR	Black	328	161
Manhatten	All-Serve	1.50	2	300	200	53	Nitrile	Nitrile/ Vinyl	Black	Reel	123
Myers Sherman	Vactor Orang	1.41	2	1250	300	--	Polyamide	Hytral	Orange	Reel	240
Porter, H.K.	G.P. Spiral	1.44	2	250	200	51	Nitrile	EPDM	Red	Reel	---
Uniroyal	P970	1.47	2	200	200	56	EPDM	EPDM	Red	Reel	133
White, H.S.	Hot Water Hose	1.47	2	250	200	65	Paracril	Ozex	Red	Reel	123

Notes:

(1) Cost based on an order of 3 lengths of 300' hoses (may require splices).
(2) Reel lengths are industry standards of 350-600 feet of hose per reel, Al maximum of 3 lengths per reel, the shortest length is at least 10% (50') of total length of hose on the reel.
(3) Baxter Rubber and Unifoyal offer identical hoses.
(4) Goodyear hose is available from both Anchor Rubber and Oberjuerge Rubber - prices quoted are Anchor Rubbers.
(5) Swan hose presently available in minimum orders of 10,000-12,000 feet.
(6) Titeflex achieves long hose lengths by non-detachable couplings joining 30 foot segments.
(7) Price include couplings and end fittings to make a 300' hose assembly.

TABLE A-2. LIST OF COMPANIES CONTACTED IN MARKET SURVEY

Company	Contacted by: Letter	Contacted by: Phone	Response (1): None Received	Response (1): Yes	Response (1): No	Comment
AMB Flex Hose	X	X			X	Metallic and plastic hose
Abbot Rubber Company	X				X	EPDM Hose
Acco Industrial Rubber Corp.	X		X		X	Conveyors, belts
Ace Hose & Rubber	X		X			Not responsive
Acme-Hamilton Manufacturing	X	X			X	Manufacturer does not think their hose is suitable
Aero-Motive Manufacturing	X				X	Cable & hose handling equipment
Aeroquip	X	X		X		
Aero Rubber	X		X			Extruded rubber
Air Products and Chemicals, Fabricated Products Div.	X				X	Plastic hoses
American Hose Corporation		X			X	Not responsive - EPDM Hose
Amazon Hose & Rubber	X	X		X		
American Biltrite Company (Boston Woven Hose)	X	X			X	Not willing to supply life support systems
American Rubber Manufacturing Company	X	X	X			Not responsive
Amelo Products	X				X	Do not manufacture hose
Alemite and Instrument (Div. of Stewart Warner)		X			X	High pressure/high cost
Anchor Coupling		X			X	Hydraulic hose - not formulated for water
Anchor Rubber	X			X		Goodyear distributer

TABLE A-2. LIST OF COMPANIES CONTACTED IN MARKET SURVEY
(Continued)

Company	Contacted by		Response (1)			Comment
	Letter	Phone	None Received	Yes	No	
Apache Hose and Rubber	X		X			Not responsive
Armstrong Hose Division, Insulated Duct & Cable Co.	X				X	Will offer hose in the future
Arrowhead Products, Division of Federal-Mobol Corp.	X				X	Special aircraft ducting
Baldwin Belting	X	X		X		Goodyear distributer
Baxter Rubber Co.	X	X		X	X	EPDM Hose
Beacon Hose Manufacturing (Cleveland Rubber Prods.)	X	X			X	Not willing to supply life support systems
Boss Manufacturing Co.	X		X			Not responsive
Boyd Industrial Rubber	X				X	EPDM Hose
Briggs Rubber Products Co.	X		X			Affiliate of Electric Hose & Rubber Special Products
Brunswick Rubber Company	X		X			
Buckeye Rubber Products	X	X			X	Mandrel made 50' lengths maximum
Carlyle Rubber Company (Carlyle Tire & Rubber)	X		X			Not responsive
Chamberlin Rubber Co.	X		X			Molded rubber goods
Chase Walton	X	X			X	75 psi max. 9' lengths max.
Cimncinati Rubber Mfg. Co. (Div. of Stewart-Warner)	X	X			X	Mandrel made 50' lengths max.
Cobon Plastics Corp.	X		X			Plastic hose only
Conti Rubber Products	X	X			X	German hose, not applicable

TABLE A-2. LIST OF COMPANIES CONTACTED IN MARKET SURVEY
(Continued)

Company	Contacted by: Letter	Contacted by: Phone	Response: None Received	Response (1): Yes	Response (1): No	Comment
Continental Rubber Works (Sub. of Continental Copper and Steel)	X	X			X	Length or temperature limitation
Controls Southeast, Inc.	X		X			Flexible metal hose and rubber jackets
Cooper Industrial Products	X				X	Mechanical Rubber products
Couse and Bolten Co.	X		X			Affliate of Cobon Plastics
Darling, R. E. Company	X		X			Special hoses (breathing) and rubber products
Dayco Rubber Products	X	X		X		
Dearborn Rubber Corp.	X		X			Not responsive
Delford Industries of Delaware	X				X	Rubber extrusions & special products
Desco	X				X	Diving equipment, but not hose
Devisch Company	X				X	Stainless steel for aero-space
Diving Unlimited International		X		X		
Durkee-Atwood	X				X	V-belts, buck sponge Rubber
Empex Industrial Hose Division, Master Processing Corp.	X				X	1-1/4" ID hose and larger
Electric Hose & Rubber Company	X	X		X		
Empire State Belting & Hose Co.	X	X			X	Not responsive
Everco Industries	X		X			Auto tubing

TABLE A-2. LIST OF COMPANIES CONTACTED IN MARKET SURVEY
(Continued)

Company	Contacted by		Response (1)			Comment
	Letter	Phone	None Received	Yes	No	
Firestone Industrial Products	X				X	Appliance, auto, special purpose
Flexco, Inc.	X		X			Not responsive
Flow Products	X		X			Hydraulic hoses and systems
Gates Rubber Company	X	X		X		
Goodall Rubber Co. (Manhatten Divison)	X					Not Responsive
Goodrich, B. F., Engineered Systems	X	X		X		
Goodyear Tire & Rubber Company Industrial Products Division	X	X		X		
Green Rubber Products	X		X			Not responsive
Hancock-Gross	X				X	Not interested in diving
Hecht Rubber Corporation	X		X		X	Rubber gasket mats
Hewitt Robbins		X			X	No longer manufactures hose
HOffman Engineering	X				X	Hose couplings
Holz Rubber Company					X	Molded rubber products and hand built hoses
Imperial-Eastman		X			X	Not for hot water
Industrial Tube	X		X			Low pressure tubing & ducting
James, E. and Co.	X		X			Not responsive
Jarvis Engineering Co.	X		X			Hose assemblies
Jason Industrial	X	X			X	Foreign manufacturer (Pirelli)
Jasper Rubber Co.	X		X			Molded & extruded products

TABLE A-2. LIST OF COMPANIES CONTACTED IN MARKET SURVEY
(Continued)

Company	Contacted by: Letter	Contacted by: Phone	Response (1): None Received	Response (1): Yes	Response (1): No	Comment
Kravex Manufacturing Corp.	X		X			Plastic hose
Manufactured Rubber Products	X		X			Extruded & molded products
Marshall Brass	X		X			LP hose & fittings
Maryland Rubber Corporation	X				X	Hydraulic hose assembly
Mercer Rubber Company	X				X	Not responsive
Murken, Frank Inc.	X		X			Stocking distributers
Miller Products Company	X		X			Subsidiary of Goodyear
Minnesota Flexible Corp.	X				X	Distributers
Moore Manufacturing	X		X			Not responsive
Mueller Belting & Supply Co.	X		X			Special products
Myers Sherman Company		X			X	3/4 & 1" hose only
New Jersey Engineering & Supply	X		X			Distributers
Oberjuerge Rubber Company	X	X		X		Goodyear distributers
Ocean Pool Supply Company	X		X			Swimming pool accessories
Parker Hannifin Corporation Hose Products	X	X		X		
Penntube Plastics Company, Division of Dixon Ind. Corp.	X		X			Unreinforced plastic extrusions
Plastiflex Company	X		X			Plastic only
Porter, H.K., Co., Inc., Thermoid Division	X	X		X		
Ramco Industries	X		X			Subsidiary of Dayco
Renick and Mahoney	X		X			Distributors

TABLE A-2. LIST OF COMPANIES CONTACTED IN MARKET SURVEY
(Continued)

Company	Contacted by Letter	Contacted by Phone	Response None Received	Response Yes (1)	Response No	Comment
Reimers Electra Steam, Inc.	X		X			Steam generators & accessories
Resistoflex Corporaton	X	X			X	Stainless steel/Teflon hose
Robin Industries	X		X			Molded rubber products
Ronco Corporation	X		X			Hose & tube fittings
Rubatex Corporation	X				X	Insulation materials
Rubber Corporation of America	X		X			Molded products
Schacht Rubber Mfg. Company	X				X	Mechanical & household rubber goods
Stalwart Rubber Company, Sub. of Blasius Ind. Inc.	X		X			Molded & extruded rubber parts
Stockwell Rubber Co., Inc.	X		X			Molded & extruded rubber parts
Stratoflex, Inc.	X				X	Stainless steel/Teflon hoses
Swan Hose Division, Amerace Corporation	X	X		X	X	(2)
Tech Aerofoam Products, Inc.	X		X			Not responsive
Trelleborg Rubber Company	X	X			X	Foreign manufacturer
Tenn-Val, Inc.	X		X			Not responsive
Titeflex Division of Atlas Corporation	X		X			Flexible metal and Teflon
Tri State Rubber Corporation	X		X			Not responsive
Unaflex Rubber Corporation	X				X	Expansion joints & pump connections, see White
United Rubber Products	X		X			Not responsive

TABLE A-2. LIST OF COMPANIES CONTACTED IN MARKET SURVEY
(Continued)

Company	Contacted by		Response (1)			Comment
	Letter	Phone	None Received	Yes	No	
Uniroyal, Inc. Uniroyal Industrial Products Div.	X	X		X		
United Rubber Supply	X		X			Not responsive
Vibration Mountings & Controls	X		X			Not responsive
Weatherhead	X	X			X	Not recommended for hot water
White, H.S. & Company	X	X		X		
Zinga Industries	X				X	Hydraulic line systems

Notes: (1) Companies with a "yes" in this column are listed in Table 1.

(2) Swan manufactures an excellent insulated hot water hose, but it is only available in quantities of 10,000 feet or more. Their representatives do not recommend use of their diving air hose for this applicaton.

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